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The Assistant Commissioner of Patents
Washington, D.C. 20231

Sir:

Attorney Docket: P56228

Submitted herewith is the following patent application:

Inventor: Young-Sun KIM

Title: FALSE CONTOUR CORRECTION APPARATUS IN IMAGE
DISPLAY SYSTEM AND FALSE CONTOUR CORRECTION
METHOD

Please find attached hereto an application for patent which includes: Specification and Abstract,
Claims, and a certified copy of the foreign priority document identified below:

Verified Showing of Small Entity Status: NO

Drawings: Formal drawings, 7 sheets, Figures 1 through 7

Claim of priority under 35 U.S.C. §119: YES

REPUBLIC OF KOREA Application No. 99-49105 filed in Korea on 6 November 1999.
REPUBLIC OF KOREA Application No. 00-65047 filed in Korea on 2 November 2000.

Fee (see formula below): **CHECK IS NOT ENCLOSED**

Basic Fee \$355/710	\$710.00
Additional Fees:	
Total number of claims in excess of 20: <u>29</u> times \$9/18.	\$522.00
Number of independent claims	
in excess of 3: <u>3</u> times \$40/80	\$240.00
Multiple Dependent Claims \$130/260	\$0.00
An Assignment is likewise enclosed: Recording Fee \$40 ..	\$0.00
Filing Non-English specification	\$ 0.00
TOTAL FEES FOR THE ABOVE APPLICATION	\$1,472.00



Assistant Commissioner of Patents
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Page Two

Docket No.: P56228

Inventor: **Young-Sun KIM**

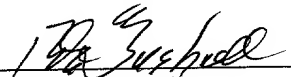
Title: **FALSE CONTOUR CORRECTION APPARATUS IN IMAGE
DISPLAY SYSTEM AND FALSE CONTOUR CORRECTION
METHOD**

In view of the above, it is requested that this application be accorded a filing date pursuant to 37 CFR 1.53(b).

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TITLE OF THE INVENTION

**FALSE CONTOUR CORRECTION APPARATUS IN IMAGE DISPLAY
SYSTEM AND FALSE CONTOUR CORRECTION METHOD**

CLAIM OF PRIORITY

This application makes reference to, incorporates the same herein, and claims all benefits accruing under 35 U.S.C. § 119 from an application entitled *False Contour Correction Apparatus in Image Display System and False Contour Correction Method* earlier filed in the Korean Industrial Property Office on 6 November 1999, and there duly assigned Serial No. 49105/1999, and an application entitled *False Contour Correction Apparatus in Image Display System and False Contour Correction Method* earlier filed in the Korean Industrial Property Office on 2 November 2000, and there duly assigned Serial No. 65047/2000.

BACKGROUND OF THE INVENTION

Technical Field

The present invention relates to an image display device and method, and more particularly, to a false contour correction apparatus in an image display system, by which a false contour at a place where conversion of the unit bits of data is severe on a display device driven in a digital system can be corrected.

Related Art

Existing types of display devices driven in a digital system include a plasma display panel (PDP), a liquid crystal display (LCD) panel, a ferroelectric liquid crystal (FLC) panel, and the like.

FLC panels have a structure in which ferroelectric liquid crystal is sandwiched between an optical planar mirror formed on a silicon substrate and glass, and have a wide viewing angle and a fast response speed compared to other panels.

In a display device driven in a digital system, distortion of picture due to an optical illusion, which is referred to as a false contour, usually occurs at a place where conversion of the unit bits of data is severe.

In a display apparatus driven in a digital system, a false contour having serious bit conversion is generated on a changing picture, for example, at the gentle boundary where a data value is changed from 63 to 64 and from 127 to 128. That is, even when a data value is changed just by one, for example, from 127 to 128, if a picture changes, data of 225 or 0 is perceived at the boundary according to the direction of the movement of the picture, resulting in a fatal degradation in the quality of image.

I have found that an image can be degraded to an undesirable level due to the false

1 contour phenomenon. Efforts have been made to reduce false contouring and improve image
2 display systems.

3 Exemplars of recent efforts in the art include U.S. Patent No. 6,072,555 to Mizutome *et*
4 *al.*, entitled *DISPLAY APPARATUS CAPABLE OF GRADATIONAL DISPLAY*, issued on June 6,
5 2000, U.S. Patent No. 5,963,190 to Tsuboyama *et al.*, entitled *DRIVING METHOD FOR*
6 *DISPLAY DEVICE AND DISPLAY APPARATUS*, issued on October 5, 1999, U.S. Patent No.
7 6,088,012 to Shigeta *et al.*, entitled *HALF TONE DISPLAY METHOD FOR A DISPLAY PANEL*,
8 issued on July 11, 2000, U.S. Patent No. 6,052,112 to Tanaka *et al.*, entitled *GRADATION*
9 *DISPLAY SYSTEM*, issued on April 18, 2000, U.S. Patent No. 5,109,282 to Peli, entitled
10 *HALFTONE IMAGING METHOD AND APPARATUS UTILIZING PYRAMIDOL ERROR*
11 *CONVERGENCE*, issued on April 28, 1992, U.S. Patent No. 6,100,939 to Kougami *et al.*,
12 entitled *tone DISPLAY METHOD AND APPARATUS FOR DISPLAYING IMAGE SIGNAL*,
13 issued on August 8, 2000, U.S. Patent No. 6,018,329 to Kida *et al.*, entitled *DRIVING SYSTEM*
14 *FOR A PLASMA DISPLAY PANEL*, issued on January 25, 2000, U.S. Patent No. 4,574,636 to
15 Satake, entitled *APPARATUS FOR EXAMINING AN OBJECT BY USING ULTRASONIC*
16 *BEAMS*, issued on March 11, 1986, U.S. Patent No. 6,134,025 to Takeuchi *et al.*, entitled *DOT*
17 *IMAGE DATA OUTPUT APPARATUS*, issued on October 17, 2000, U.S. Patent No. 5,706,063
18 to Hong, entitled *OPTICAL SYSTEM OF A REFLECTION LCD PROJECTOR*, issued on
19 January 6, 1998; Japanese Patent No. 11-6980 to Miyashita, entitled *PROJECTION DEVICE*,
20 published on January 12, 1999, Japanese Patent No. 8-168039 too Nomura *et al.*, entitled

1 *PROJECTION DISPLAY SYSTEM AND PROJECTION POSITION ADJUSTING METHOD*,
2 published on 25 June 1996, Japanese Patent No. 09-90402 to Takigawa *et al.*, entitled *PICTURE*
3 *DISPLAY DEVICE*, published on 4 April 1997, Japanese Patent No. 10-123477 to Yoneda *et al.*,
4 entitled *LIQUID CRYSTAL PROJECTOR*, published on 15 May 1998, Japanese Patent No. 10-
5 23445 to Semasa, entitled *PICTURE DISPLAY DEVICE*, published on 23 January 1998,
6 Japanese Patent No. 08-294138 to Ozuru *et al.*, entitled *LIQUID CRYSTAL PROJECTOR*,
7 published on 5 November 1996, and Japanese Patent No. 10-148885 to Murakami *et al.*, entitled
8 *PROJECTOR APPARATUS*, issued on 2 June 1998.

9 While these recent efforts provide advantages, I note that they fail to adequately provide a
10 false contour correction apparatus and method in an image display system.

SUMMARY OF THE INVENTION

11 To solve the above problems and others, an objective of the present invention is to
12 provide a false contour correction apparatus in an image display system, by which a false contour
13 is corrected by reversely symmetrically arranging the bits of two digital display panels, which are
14 driven in a digital system, so that one digital display panel displays data in the order from the
15 most significant bit to the least significant bit while the other digital display panel displays data
16 in the order from the least significant bit to the most significant bit.
17

18 To solve the above problems and others, an objective of the present invention is to

1 provide a false contour correction method in an image display system, by which a false contour is
2 corrected by reversely symmetrically arranging the bits of two digital display panels, which are
3 driven in a digital system, so that one digital display panel displays data in the order from the
4 most significant bit to the least significant bit while the other digital display panel displays data
5 in the order from the least significant bit to the most significant bit.

6 To achieve these and other objects in accordance with the principles of the present
7 invention, as embodied and broadly described, the present invention provides a false contour
8 correction apparatus in an image display system driven in a digital system, the apparatus
9 including: a controller for receiving R, G and B signals and outputting R, G and B data for
10 driving two digital display panel by performing a predetermined signal processing, in accordance
11 with a synchronization signal; and an optical engine for receiving R, G and B data from the
12 controller and outputting image data to a screen via a first digital display panel for displaying
13 data in a sequence from the most significant bit to the least significant bit and a second digital
14 display panel for displaying data in a sequence from the least significant bit to the most
15 significant bit.

16 To achieve these and other objects in accordance with the principles of the present
17 invention, as embodied and broadly described, the present invention provides a false contour
18 correcting method in an image display system for displaying received image data on two digital
19 display panels, wherein the first digital display panel arranges the bits of the image data so that

1 the image data is driven and displayed in the order from the most significant bit to the least
2 significant bit, and the second digital display panel arranges the bits of the image data so that the
3 image data is driven and displayed in the order from the least significant bit to the most
4 significant bit.

5 To achieve these and other objects in accordance with the principles of the present
6 invention, as embodied and broadly described, the present invention provides an image display
7 apparatus correcting false contour, comprising: a first light beam splitter passing a first
8 wavelength band of a plurality of colored lights received, reflecting a second wavelength band of
9 said plurality of colored lights received; a first panel receiving said first wavelength band of said
10 plurality of colored lights, receiving color data and panel control signals, outputting first incident
11 light corresponding to said received color data in accordance with said panel control signals to
12 display said received color data starting from most significant bit to least significant bit; and a
13 second panel receiving said second wavelength band of said plurality of colored lights, receiving
14 said color data and panel control signals, outputting second incident light corresponding to said
15 received color data in accordance with said panel control signals to display said received color
16 data starting from least significant bit to most significant bit.

17 To achieve these and other objects in accordance with the principles of the present
18 invention, as embodied and broadly described, the present invention provides an image display
19 apparatus, comprising: a control unit receiving color signals and synchronization signals,

1 outputting color switch signals in accordance with said synchronization signals, outputting color
2 data corresponding to said received color signals, outputting panel control signals; a light unit
3 emitting white light; a color switching unit receiving the white light from said first lens,
4 receiving said color switch signals from said control unit, separating the white light into a
5 plurality of colored lights, outputting each one of said plurality of colored lights seriatim in
6 response to said color switch signals; a first panel receiving P wavelength components of said
7 plurality of colored lights outputted from said color switching unit, receiving said color data and
8 panel control signals outputted by said control unit, outputting first incident light corresponding
9 to said received color data applied by said control unit to data lines of each cell formed as a
10 matrix in accordance with said panel control signals to display said received color data starting
11 from most significant bit to least significant bit; and a second panel receiving S wavelength
12 components of said plurality of colored lights outputted from said color switching unit, receiving
13 said color data and panel control signals outputted by said control unit, outputting second
14 incident light corresponding to said received color data applied by said control unit to data lines
15 of each cell formed as a matrix in accordance with said panel control signals to display said
16 received color data starting from least significant bit to most significant bit.

17 To achieve these and other objects in accordance with the principles of the present
18 invention, as embodied and broadly described, the present invention provides an image display
19 apparatus, comprising: a light unit emitting light; a color switching unit receiving the light from
20 said light unit, receiving color switch signals, separating the light into a plurality of colored

1 lights, outputting each one of said plurality of colored lights seriatim in response to said color
2 switch signals; a light beam splitter passing a first wavelength band of said plurality of colored
3 lights received from said color switching unit, reflecting a second wavelength band of said
4 plurality of colored lights received from said color switching unit; a first panel receiving said first
5 wavelength band of said plurality of colored lights, receiving color data and panel control signals,
6 reflecting first incident light corresponding to said received color data applied to data lines of
7 each cell formed as a matrix in accordance with said panel control signals to display said
8 received color data starting from most significant bit to least significant bit; a second panel
9 receiving said second wavelength band of said plurality of colored lights, receiving said color
10 data and panel control signals, reflecting second incident light corresponding to said received
11 color data applied to data lines of each cell formed as a matrix in accordance with said panel
12 control signals to display said received color data starting from least significant bit to most
13 significant bit; said light beam splitter receiving first and second reflected incident light from
14 said first and second panels respectively, passing said first wavelength band of said second
15 incident light reflected by said second panel, reflecting said second wavelength band of said first
16 incident light reflected by said first panel; and a screen receiving said first wavelength band of
17 light passed by said light beam splitter and said second wavelength band of light reflected by said
18 light beam splitter.

19 To achieve these and other objects in accordance with the principles of the present
20 invention, as embodied and broadly described, the present invention provides a method of

1 displaying an image on an image display apparatus, comprising: emitting light from a light unit;
2 receiving the light from said light unit and receiving color switch signals, separating the received
3 light into a plurality of colored lights and outputting each one of said plurality of colored lights
4 seriatim in accordance with said color switch signals, said separating being performed by a color
5 switch unit; passing a first wavelength band of said plurality of colored lights outputted from said
6 color switching unit and reflecting a second wavelength band of said plurality of colored lights
7 outputted from said color switching unit; receiving said first wavelength band of said plurality of
8 colored lights, receiving first color data and first panel control signals, transmitting first incident
9 light corresponding to said received first color data in accordance with said first panel control
10 signals to display said received first color data starting from most significant bit to least
11 significant bit, said receiving of said first wavelength band being performed by a first panel;
12 receiving said second wavelength band of said plurality of colored lights, receiving second color
13 data and second panel control signals, transmitting second incident light corresponding to said
14 received second color data in accordance with said second panel control signals to display said
15 received second color data starting from least significant bit to most significant bit, said receiving
16 of said second wavelength band being performed by a second panel; receiving first and second
17 incident light from said first and second panels respectively, passing said second wavelength
18 band of said second incident light transmitted by said second panel, reflecting said first
19 wavelength band of said first incident light transmitted by said first panel; and receiving and
20 displaying on a screen said second wavelength band of said second incident light transmitted and
21 said first wavelength band of said first incident light reflected.

1 To achieve these and other objects in accordance with the principles of the present
2 invention, as embodied and broadly described, the present invention provides a false contour
3 correction apparatus in an image display system driven in a digital system, the apparatus
4 comprising: a controller receiving a plurality of colored signals, performing a predetermined
5 signal processing, and outputting color data in accordance with said signal processing; and an
6 optical unit receiving said outputted color data, outputting image data corresponding to said
7 outputted color data to a screen via a first light path by displaying data in a sequence from most
8 significant bit to least significant bit and via a second light path by displaying data in a sequence
9 from least significant bit to most significant bit.

10 To achieve these and other objects in accordance with the principles of the present
11 invention, as embodied and broadly described, the present invention provides a false contour
12 correcting method in an image display system, comprising: receiving image data and supplying
13 said image data to a first display arranging bits of said image data so that said image data is
14 driven and displayed in order from most significant bit to least significant bit; and supplying said
15 image data to a second display arranging bits of said image data so that said image data is driven
16 and displayed in order from least significant bit to most significant bit.

17 The present invention is more specifically described in the following paragraphs by
18 reference to the drawings attached only by way of example. Other advantages and features will
19 become apparent from the following description and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings, which are incorporated in and constitute a part of this specification, embodiments of the invention are illustrated, which, together with a general description of the invention given above, and the detailed description given below, serve to exemplify the principles of this invention.

FIG. 1 is a block diagram illustrating the structure of a display device using a ferroelectric liquid crystal (FLC) panel;

FIG. 2 is a detailed configuration view of the optical engine of FIG. 1;

FIG. 3 is a block diagram illustrating the structure of a false contour correction apparatus in an image display system, in accordance with the principles of the present invention;

FIG. 4 shows the arrangement sequence of the bits of data on an LCD panel in a false contour correction method in an image display system, in accordance with the principles of the present invention;

FIG. 5 is a detailed configuration of a first embodiment of the optical engine of FIG. 3, in accordance with the principles of the present invention;

FIG. 6 is a detailed configuration of a second embodiment of the optical engine of FIG. 3, in accordance with the principles of the present invention; and

FIG. 7 shows a displayed bit specification of LCD data to explain false contour correction, in accordance with the principles of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

While the present invention will be described more fully hereinafter with reference to the accompanying drawings, in which a preferred embodiment of the present invention is shown, it is to be understood at the outset of the description which follows that persons of skill in the appropriate arts may modify the invention here described while still achieving the favorable results of this invention. Accordingly, the description which follows is to be understood as being a broad, teaching disclosure directed to persons of skill in the appropriate arts, and not as limiting upon the present invention.

As shown in FIG. 1, a display device using an FLC display panel is made up of a signal processing unit 101, a timing control unit 102, an optical engine 103 and a screen 104. As shown in FIG. 2, the optical engine 103 is made up of an optical source 201, a collimating lens 202, a color switching means 203, a polarized beam splitter 204, an FLC panel 205, and a projection lens 206.

The signal processing unit 101 receives R, G, and B (red, green, and blue) signals, controls the offset, contrast and brightness of the received signals, performs signal processing such as gamma correction, and then generates R/G/B data to be displayed on the FLC panel on a field-by-field basis in synchronization with a vertical synchronization signal and also generates a clock and panel control signal for controlling an FLC panel.

The timing control unit 102 receives a vertical synchronization signal and a horizontal synchronization signal, and generates a color switching control signal for controlling the color switching means 203.

The operation of displaying R/G/B data output from the signal processing unit 101 on the screen 104 will now be described with reference to FIG. 2. The optical source 201 is made up of a lamp for producing light, and a reflective mirror for reflecting light emitted from the lamp to guide the light, and radiates light.

The collimating lens 202 focuses light radiated from the optical source 201 into parallel light or focusing light. The color switching means 203 is an LCD shutter or a color wheel type, and receives white light from the collimating lens 202 and sequentially switches and outputs three colors R, G and B at intervals of a 1/3 vertical period during one vertical period according to a color switching control signal received from the timing control unit 102. That is, during the first 1/3 vertical period, only the wavelength of the color R among the received light is transmitted, while the remaining wavelengths are blocked. Then, the wavelength of each of the colors G and B is switched and transmitted during a 1/3 vertical period.

The polarized beam splitter 204 reflects an S wave among light received from the color switching means 203 and guides the reflected S wave to the FLC panel 205, and transmits a P wave. The FLC panel 205 reflects incident light to the polarized beam splitter 204 in accordance

1 with the R/G/B data values applied by the signal processing unit 101 to the data lines of each cell
2 formed as a matrix, under the control of a clock and panel control signal, thereby displaying the
3 image of each pixel.

4 Then, the polarized beam splitter 204 transmits a P wave among light reflected by the
5 FLC panel 205 and guides the P wave to the projection lens 206, and reflects an S wave. The
6 projection lens 206 magnifies the light received from the polarized beam splitter 204 and projects
7 the magnified light toward the screen 207.

8 As shown in FIG. 3, a false contour correction apparatus in an image display system
9 according to the present invention includes a controller 301, an optical engine 302 and a screen
10 303. In the controller 301, a signal processing unit receives R, G and B signals, controls the
11 offset, the contrast and the brightness, performs signal processing such as gamma correction, and
12 then outputs R/G/B data for driving two liquid crystal display (LCD) panels, in accordance with a
13 vertical synchronization signal. Also, the signal processing unit generates control signals for
14 driving LCD panels.

15 A timing control unit in the controller 301 generates a color switching control signal for
16 controlling the R, G, B color switching of a color switching means included in the optical engine
17 302, in accordance with a synchronization signal. As described above, the R, G and B data
18 output from the controller 301 is applied to the LCD panels of the optical engine 302, and the

LCD panel transmits or reflects incident light R, G and B corresponding to the values of the R, G and B data to display images.

The operation of the optical engine 302 will now be described with reference to FIG. 5. As shown in FIG. 5, the optical engine 302 includes an optical source 501, a collimating lens 502, a color switching means 503, first and second polarized beam splitters 504 and 505, first and second LCD panels 506 and 507, first and second reflective mirrors 508 and 509 and a projection lens 510.

The optical source 501 is made up of a lamp for producing light, and a reflective mirror for reflecting light emitted from the lamp to guide the light, and radiates light. The collimating lens 502 focuses light irradiated from the optical source 501 into parallel light or focusing light.

The color switching means 503 is an LCD shutter or a color wheel type, and receives white light from the collimating lens 502 and sequentially switches and outputs three colors R, G and B at intervals of 1/3 of a vertical period during one vertical period in accordance with a color switching control signal received from the controller 301. That is, during the first 1/3 vertical period, only the wavelength of R color among the received light is transmitted, while the remaining wavelengths are blocked. Then, the wavelengths of the colors G and B are sequentially switched and transmitted during the remaining two 1/3 vertical periods.

1 The first polarized beam splitter 504 transmits, for example, a P wave among light
2 received from the color switching means 503, and reflects an S wave to change the travel
3 direction of the S wave by 90 degrees. The first reflective mirror 508 reflects incident light
4 transmitted by the first polarized beam splitter 504 and guides the reflected light to the first LCD
5 panel 506 (LCD #1), and the second reflective mirror 509 reflects incident light reflected by the
6 first polarized beam splitter 504 and guides the reflected light to the second LCD panel 507
7 (LCD #2).

8 The first LCD panel 506 is installed on the path of light reflected by the first reflective
9 mirror 508, and transmits incident light corresponding to the data values of R, G and B applied
10 by the controller 301 to the data lines of each cell formed as a matrix, according to a clock and
11 panel control signal. That is, the first LCD panel 506 displays the R/G/B data received from the
12 controller 301 each in a sequence starting from the most significant bit to the least significant bit,
13 as shown in LCD #1 of FIG. 4.

14 The second LCD panel 507 is installed on the path of light reflected by the second
15 reflective mirror 509, and transmits incident light corresponding to the data values of R, G and B
16 applied to the data lines of each cell formed as a matrix, according to a clock and panel control
17 signal, as in the first LCD panel 506. As shown in LCD #2 of FIG. 4, the second LCD panel 507
18 displays the Ro, Go and Bo data from the controller 301 each in a sequence starting from the
19 least significant bit to the most significant bit, opposite to the LCD #1. That is, a false contour is

removed by the bit arrangements made by the first and second LCD panels 506 and 507 in the opposite orders.

Hereinafter, the removal of false contour by the bit arrangements made by the first and second LCD panels 506 and 507 according to the present invention will be described by referring to only red data among the data R, G and B, for convenience of explanation.

If data is set to be composed of 5 bits, the first LCD panel 506 displays data in the order from MSB b4 to LSB b0, and the second LCD panel 507 displays data in the order from LSB b0 to MSB b4 which is opposite to the first LCD panel 506.

Consequently, when a data value of 15 is converted into a data value of 16, data is shown brightly with a data value of 31 in the first LCD (LCD #1) panel 506, and data becomes dark with a data value of 0 in the second LCD (LCD #2) panel 507, as shown in FIG. 7. Thus, a data value of 15.5, which is the average of the data values of the first and second LCD panels 506 and 507, is perceived by eyes, so that false contour is removed.

The second polarized beam splitter 505 transmits P wave light among light received from the first and second LCD panels 506 and 507, and reflects S wave light so that the travel direction of the S wave light from the first LCD panel 506 is consistent with that of the P wave light from the second LCD panel 507. The projection lens 510 magnifies and projects the light

1 received from the polarized beam splitter 505 toward the screen 511.

2 The operation of a second embodiment of the optical engine 302 will now be described
3 with reference to FIG. 6. The first embodiment of the optical engine 302 use transmissive LCD
4 panels, but the second embodiment uses reflective ferroelectric liquid crystal (FLC) panels.

5 A transmissive LCD panel displays an image by transmitting incident light corresponding
6 to a data value input to the data line of the transmissive LCD panel, and a reflective FLC panel
displays an image by reflecting incident light corresponding to a data value input to the data line
of the reflective FLC panel.

9 The second embodiment of the optical engine 302 includes an optical source 601, a
10 collimating lense 602, a color switching unit 603, a polarized beam splitter 604, first and second
FLC panels 605 and 606 and a projection lens 607.

12 The optical source 601 is made up of a lamp for producing light and a reflective mirror
13 for reflecting light emitted from the lamp to guide the light, and radiates light. The collimating
14 lens 602 focuses light irradiated from the optical source 601 into a parallel beam or focusing
15 beam.

16 The color switching unit 603 is an LCD shutter or a color wheel type, and receives white

1 color light from the collimating lense 602 and sequentially switches and outputs three colors R,
2 G and B during one vertical period under the control of a color switching control signal received
3 from the controller 301. That is, during a first $1/3$ vertical period, only the wavelength of the
4 color R among the received light is transmitted, while the remaining wavelengths are blocked.
5 Then, the wavelengths of the colors G and B are sequentially switched and transmitted during the
6 remaining two $1/3$ vertical periods.

7 The polarized beam splitter 604 transmits, for example, P wave light among light
8 received from the color switching unit 603 and guides the P wave light toward the second FLC
9 panel 606, and reflects an S wave light to change the direction of travel of light by 90 degrees
10 and guides the reflected S wave light toward the first FLC panel 605.

11 The first and second FLC panels 605 and 606 reflect the incident light beams
12 corresponding to the R/G/B data values applied by the controller 301 to the data lines of each cell
13 formed as a matrix, under the control of the clock and panel control signal, thereby displaying the
14 image of each pixel. The first and second FLC panels 605 and 606 arrange bits in the opposite
15 orders to remove a false contour, as shown in FIG. 4.

16 Then, the polarized beam splitter 604 transmits P wave light among light reflected by the
17 first FLC panel 605, and reflects S wave light among light reflected by the second FLC panel 606
18 so that the travel path of the S wave light is consistent with that of the P wave light. The

1 projection lens 607 magnifies the light received from the polarized beam splitter 604 and projects
2 it toward the screen 608.

3 Please refer now to Figure 4. The Figure 4 shows a timing diagram of a three color
4 sequence (R then G then B) according to a method of compensating for false contour, in
5 accordance with the principles of the present invention. Figure 4 shows red (R) data in detail,
6 which is followed by symbols G and B representing green data and blue data. In Figure 4, the red
7 data can have a minimum brightness level of 0 and a maximum brightness level of 31, because
8 five bits are used for indicating the brightness level. The five bits are b4, b3, b2, b1, and b0. The
9 minimum brightness level 0 exists when each one of the five bits is equal to zero, which is
10 00000. The maximum brightness level 31 exists when each one of the five bits is equal to one,
11 which is 11111. The most significant bit is b4. The least significant bit is b0.

12 As shown in Figure 4 for liquid crystal display panel #1 (LCD #1), the data bits are
13 ordered so that the least significant bit b0 is output first, and the most significant bit b4 is output
14 last. As shown in Figure 4 for liquid crystal display panel #2 (LCD #2), the bits are ordered so
15 that the most significant bit b4 is output first, and the least significant bit b0 is output last. The
16 data bits are output from LCD#1 and from LCD#2 substantially simultaneously, and the two data
17 streams are output to a screen substantially simultaneously, and the two data streams are viewed
18 by a user substantially simultaneously. In this manner, a false contour phenomenon is reduced or
19 removed.

1 Please refer now to Figure 7. The Figure 7 shows a correction of false contour, in
2 accordance with the principles of the present invention. In Figure 7, five bits are used for
3 indicating a brightness level. The five bits are b4, b3, b2, b1, and b0. The most significant bit is
4 b4. The least significant bit is b0.

5 In Figure 7, a transition from brightness level 15 to brightness level 16 is illustrated, in
6 accordance with the principles of the present invention. A brightness level of a pixel could
7 transition from level 15 to level 16 at a certain moment while a movie was being shown on a
8 high definition television (HDTV), for example.

9 Brightness level 15 is depicted in Frame 1 on Figure 7. Brightness level 16 is depicted in
10 Frame 2 on Figure 7. Frame 1 is earlier in time than Frame 2. Frame 2 corresponds to a
11 brightness level of a particular pixel after that particular pixel had a brightness level
12 corresponding to Frame 1, for example. In Figure 7, a ferroelectric liquid crystal display panel
13 #1 (FLC #1) and a ferroelectric liquid crystal display panel #2 (FLC #2) are shown to be
14 outputting data corresponding to brightness levels.

15 The FLC #1 of Figure 7 is shown to be outputting data corresponding to a brightness
16 level of 15 in Frame 1. The FLC #1 in Frame 1 is outputting five data bits b4=0, b3=1, b2=1,
17 b1=1, and b0=1. The brightness level 15 corresponds to bit values 01111. After Frame 1, the
18 Frame 2 is depicted. In Frame 2, the FLC #1 is shown to be outputting data corresponding to a

1 brightness level of 16. In Frame 2 the FLC #1 is outputting five data bits b4=1, b3=0, b2=0,
2 b1=0, and b0=0. The brightness level 16 corresponds to bit values 10000.

3 The FLC #2 of Figure 7 is shown to be outputting data corresponding to a brightness
4 level in an order where the bits are reversed from the order of FLC #1. The FLC #2 is shown to
5 be outputting data corresponding to a brightness level of 15 in Frame 1, with the bits in reverse
6 order. In Frame 1 the FLC #2 is outputting five data bits b4=0, b3=1, b2=1, b1=1, and b0=1.
7 The brightness level 15 corresponds to bit values 01111. In Frame 1 for FLC #2, the bits are
8 output in reverse order so that they are depicted as 11110. After Frame 1, the Frame 2 is
9 depicted. In Frame 2, the FLC #2 is shown to be outputting data corresponding to a brightness
10 level of 16 with the bits in reverse order. In Frame 2 the FLC #2 is outputting five data bits
11 b4=1, b3=0, b2=0, b1=0, and b0=0. The brightness level 16 corresponds to bit values 10000. In
12 Frame 2 for FLC #2, the bits are output in reverse order so that they are depicted as 00001.

13 In a device which does not utilize the apparatus and method of the present invention,
14 there will be a problem when a brightness level changes from brightness level 15 to brightness
15 level 16. The problem is known as false contour. Even though the change from level 15 to level
16 16 is a small change, an image will have a degraded quality on a device which does not utilize
17 the apparatus and method of the present invention.

18 In a device which does not utilize the apparatus and method of the present invention,

1 when a brightness level changes from level 15 (which corresponds to 01111) to level 16 (which
2 corresponds to 10000), false contour will occur at the picture having a change from 15 brightness
3 to 16 brightness, and the brightness level is changed to brightness level 31 or 0 at the interface
4 between frames or fields. As a false contour, a white line or black picture appears on the screen.

5 However, in the present invention as shown in Figures 3-7, the false contour can be
6 controlled regardless of the order of bit because FLC #1 and FLC #2 are arranged to output data
7 bits in forward order and reverse order, respectively. Figure 4 shows the horizontal line as a time
8 domain. Figure 7 shows the brightness level of R signal and indicates an example of 15
9 brightness and 16 brightness levels at which a bit reversion occurs between the first R (Frame 1)
10 and the second R (Frame 2). In Figure 7, the hatched or shaded areas correspond to bits having a
11 value of 1 (one). In Figure 7, the unshaded areas correspond to bits having a value of 0 (zero).

12 In a device which does not utilize the apparatus and method of the present invention, the
13 brightness level can be changed to 31 at an interface between frames even though there is only
14 one level between brightness level 15 and brightness level 16. That is the false contour
15 phenomenon.

16 However, in the present invention as shown in Figures 3-7, when two panels are disposed
17 to be in reverse order, the contour portion becomes 31 and 0 (zero). Therefore, an average
18 brightness level of contour becomes $(31+0)/2=15.5$, and the contour is compensated smoothly.

1 In the specification, a digital display panel has been described by being limited to a
2 transmissive LCD panel or reflective FLC panel, for convenience of explanation. However, it is
3 apparent that the present invention can be applied to other types of digital display panels.

4 The above-described optical engines have been simplified for convenience of
5 explanation. However, it is apparent to one of ordinary skill in the optical engine designing
6 techniques that the optical engines can further include a glass polarizer, various shutters, cubes,
7 and the like in order to improve the quality of image such as contrast, and that the location of
8 collimating lenses can be changed.

9 According to the present invention as described above, received image data is displayed
10 by reversely symmetrically arranging the bits of two digital driving display means, so that fatal
11 false contour during digital driving can be removed.

12 While the present invention has been illustrated by the description of embodiments
13 thereof, and while the embodiments have been described in considerable detail, it is not the
14 intention of the applicant to restrict or in any way limit the scope of the appended claims to such
15 detail. Additional advantages and modifications will readily appear to those skilled in the art.
16 Therefore, the invention in its broader aspects is not limited to the specific details, representative
17 apparatus and method, and illustrative examples shown and described. Accordingly, departures
18 may be made from such details without departing from the spirit or scope of the applicant's

—

What is claimed is:

1 1. An image display apparatus correcting false contour, comprising:
2 a first light beam splitter passing a first wavelength band of a plurality of colored lights
3 received, reflecting a second wavelength band of said plurality of colored lights received;
4 a first panel receiving said first wavelength band of said plurality of colored lights,
5 receiving color data and panel control signals, outputting first incident light corresponding to said
6 received color data in accordance with said panel control signals to display said received color
7 data starting from most significant bit to least significant bit; and
8 a second panel receiving said second wavelength band of said plurality of colored lights,
9 receiving said color data and panel control signals, outputting second incident light
10 corresponding to said received color data in accordance with said panel control signals to display
11 said received color data starting from least significant bit to most significant bit.

1 2. The apparatus of claim 1, further comprising:
2 a second light beam splitter receiving first and second incident light from said first and
3 second panels respectively, passing said second wavelength band of said second incident light
4 outputted by said second panel, reflecting said first wavelength band of said first incident light
5 outputted by said first panel; and
6 a screen receiving said second wavelength band of light passed by said second light beam
7 splitter and said first wavelength band of light reflected by said second light beam splitter.

1 3. The image display apparatus of claim 1, further comprising:

2 a light unit emitting the white light;

3 a color switching unit receiving the white light from said light unit, receiving color switch
4 signals, separating the white light into said plurality of colored lights, outputting each one of said
5 plurality of colored lights seriatim in response to said color switch signals; and

6 a first lens collimating the light received from said light unit and outputting the
7 collimated light to said color switching unit.

1 4. The apparatus of claim 2, said color data and panel control signals received by
2 said first panel corresponding to first color data and first panel control signals, said color data and
3 panel control signals received by said second panel corresponding to second color data and
4 second panel control signals distinguishable from said first color data and first panel control
5 signals.

1 5. The apparatus of claim 2, further comprising a control unit receiving color signals
2 and synchronization signals, outputting said color switch signals in accordance with said
3 synchronization signals, outputting said color data corresponding to said received color signals,
4 outputting said panel control signals.

1 6. The apparatus of claim 5, said control unit controlling offset, contrast, and

brightness of the received color signals.

7. The apparatus of claim 5, said control unit performing signal processing on the received color signals including gamma correction.

8. The apparatus of claim 5, said control unit further comprising:
a signal processing unit receiving said color signals, outputting said color data and said panel control signals; and
a timing control unit receiving said synchronization signals, outputting said color switch signals.

9. The apparatus of claim 8, said synchronization signals corresponding to horizontal and vertical synchronization signals.

10. The apparatus of claim 2, further comprising:
a first mirror reflecting said first wavelength received from said first light beam splitter, said first panel receiving said first wavelength reflected by said first mirror; and
a second mirror reflecting said second wavelength received from said first light beam splitter, said second panel receiving said second wavelength reflected by said second mirror.

11. The apparatus of claim 2, said color switching unit outputting each one of said

2 plurality of colored lights seriatim at intervals of $1/3$ of a period in accordance with said color
3 switch signals.

1 12. The apparatus of claim 11, said plurality of colored lights output from said color
2 switching unit corresponding to red light, green light, and blue light.

1 13. The apparatus of claim 2, said color switching unit outputting a first colored light
2 of said plurality of colored lights while blocking all other colored lights of said plurality of
3 colored lights.

1 14. The apparatus of claim 2, said color data output from said control unit
2 corresponding to first color data output to said first panel and second color data output to said
3 second panel, said first and second color data being distinguishable from each other.

1 15. The apparatus of claim 2, said panel control signals output from said control unit
2 corresponding to first panel control signals output to said first panel and second panel control
3 signals output to said second panel, said first and second panel control signals being
4 distinguishable from each other.

1 16. The apparatus of claim 2, said first and second panels corresponding to liquid
2 crystal display panels.

1 17. The apparatus of claim 2, said color switching unit corresponding to one selected
2 from among a liquid crystal display shutter and a color wheel.

1 18. An image display apparatus, comprising:
2 a control unit receiving color signals and synchronization signals, outputting color switch
3 signals in accordance with said synchronization signals, outputting color data corresponding to
4 said received color signals, outputting panel control signals;
5 a light unit emitting white light;
6 a color switching unit receiving the white light from said light unit, receiving said color
7 switch signals from said control unit, separating the white light into a plurality of colored lights,
8 outputting each one of said plurality of colored lights seriatim in response to said color switch
9 signals;
10 a first panel receiving P wavelength components of said plurality of colored lights
11 outputted from said color switching unit, receiving said color data and panel control signals
12 outputted by said control unit, outputting first incident light corresponding to said received color
13 data applied by said control unit to data lines of each cell formed as a matrix in accordance with
14 said panel control signals to display said received color data starting from most significant bit to
15 least significant bit; and
16 a second panel receiving S wavelength components of said plurality of colored lights
17 outputted from said color switching unit, receiving said color data and panel control signals

18 outputted by said control unit, outputting second incident light corresponding to said received
19 color data applied by said control unit to data lines of each cell formed as a matrix in accordance
20 with said panel control signals to display said received color data starting from least significant
21 bit to most significant bit.

1 19. The apparatus of claim 18, further comprising:

2 a first lens collimating the white light received from said light unit, outputting the
3 collimated white light to said color switching unit;

4 a first light beam splitter passing said P wavelength components, reflecting said S
5 wavelength components;

6 a second light beam splitter receiving said first and second incident light from said first
7 and second panels respectively, passing said S wavelength components of said second incident
8 light outputted by said second panel, reflecting said P wavelength components of said first
9 incident light outputted by said first panel; and

10 a screen receiving and displaying light received from said second light beam splitter.

1 20. The apparatus of claim 19, said color switching unit outputting each one of said
2 plurality of colored lights seriatim at intervals of 1/3 of a period in accordance with said color
3 switch signals.

1 21. The apparatus of claim 19, said plurality of colored lights output from said color

switching unit comprising red light, green light, and blue light.

22. The apparatus of claim 21, said color switching unit outputting one of said plurality of colored lights while blocking the others of said plurality of colored lights.

23. The apparatus of claim 19, said color switching unit outputting a first colored light of said plurality of colored lights while blocking all other colored lights of said plurality of colored lights.

24. The apparatus of claim 19, said color data output from said control unit corresponding to first color data output to said first panel and second color data output to said second panel, said first and second color data being distinguishable from each other.

25. The apparatus of claim 24, said panel control signals output from said control unit corresponding to first panel control signals output to said first panel and second panel control signals output to said second panel, said first and second panel control signals being distinguishable from each other.

26. The apparatus of claim 19, said panel control signals output from said control unit corresponding to first panel control signals output to said first panel and second panel control signals output to said second panel.

1 27. The apparatus of claim 19, said first and second panels corresponding to liquid
2 crystal display panels.

1 28. The apparatus of claim 19, said color switching unit corresponding to one selected
2 from among a liquid crystal display shutter and a color wheel.

1 29. An image display apparatus, comprising:
2 a light unit emitting light;
3 a color switching unit receiving the light from said light unit, receiving color switch
4 signals, separating the light into a plurality of colored lights, outputting each one of said plurality
5 of colored lights seriatim in response to said color switch signals;
6 a light beam splitter passing a first wavelength band of said plurality of colored lights
7 received from said color switching unit, reflecting a second wavelength band of said plurality of
8 colored lights received from said color switching unit;
9 a first panel receiving said first wavelength band of said plurality of colored lights,
10 receiving color data and panel control signals, reflecting first incident light corresponding to said
11 received color data applied to data lines of each cell formed as a matrix in accordance with said
12 panel control signals to display said received color data starting from most significant bit to least
13 significant bit;
14 a second panel receiving said second wavelength band of said plurality of colored lights,

receiving said color data and panel control signals, reflecting second incident light corresponding to said received color data applied to data lines of each cell formed as a matrix in accordance with said panel control signals to display said received color data starting from least significant bit to most significant bit;

said light beam splitter receiving first and second reflected incident light from said first and second panels respectively, passing said first wavelength band of said second incident light reflected by said second panel, reflecting said second wavelength band of said first incident light reflected by said first panel; and

a screen receiving said first wavelength band of light passed by said light beam splitter and said second wavelength band of light reflected by said light beam splitter.

30. The apparatus of claim 29, said color switching unit outputting each one of said plurality of colored lights seriatim in accordance with said color switch signals.

31. The apparatus of claim 29, said plurality of colored lights output from said color switching unit corresponding to red light, green light, and blue light.

32. The apparatus of claim 29, said color switching unit outputting a first colored light of said plurality of colored lights while blocking all other colored lights of said plurality of colored lights.

1 33. The apparatus of claim 29, said first and second panels corresponding to reflective
2 ferroelectric liquid crystal panels.

1 34. The apparatus of claim 29, said color switching unit corresponding to one selected
2 from among a color wheel and an electric shutter.

1 35. A method of displaying an image on an image display apparatus, comprising:
2 emitting light from a light unit;
receiving the light from said light unit and receiving color switch signals, separating the
received light into a plurality of colored lights and outputting each one of said plurality of
colored lights seriatim in accordance with said color switch signals, said separating being
performed by a color switch unit;

passing a first wavelength band of said plurality of colored lights outputted from said
color switching unit and reflecting a second wavelength band of said plurality of colored lights
outputted from said color switching unit;

receiving said first wavelength band of said plurality of colored lights, receiving first
color data and first panel control signals, transmitting first incident light corresponding to said
received first color data in accordance with said first panel control signals to display said
received first color data starting from most significant bit to least significant bit, said receiving of
said first wavelength band being performed by a first panel;

receiving said second wavelength band of said plurality of colored lights, receiving

second color data and second panel control signals, transmitting second incident light corresponding to said received second color data in accordance with said second panel control signals to display said received second color data starting from least significant bit to most significant bit, said receiving of said second wavelength band being performed by a second panel;

receiving first and second incident light from said first and second panels respectively, passing said second wavelength band of said second incident light transmitted by said second panel, reflecting said first wavelength band of said first incident light transmitted by said first panel; and

receiving and displaying on a screen said second wavelength band of said second incident light transmitted and said first wavelength band of said first incident light reflected.

36. The method of claim 35, further comprising collimating the light received from said light unit and outputting the collimated light to said color switching unit.

37. The method of claim 35, said color switching unit outputting each one of said plurality of colored lights seriatim in accordance with said color switch signals.

38. The method of claim 37, said plurality of colored lights output from said color switching unit corresponding to red light, green light, and blue light.

1 39. The method of claim 35, said color switching unit outputting a first colored light
2 of said plurality of colored lights while blocking all other colored lights of said plurality of
3 colored lights.

1 40. The method of claim 39, said first and second panels being selected from among
2 transmissive and reflective liquid crystal display panels.

1 41. The method of claim 40, said color switching unit corresponding to one selected
2 from among a liquid crystal display shutter and a color wheel.

1 42. A false contour correction apparatus in an image display system driven in a digital
2 system, the apparatus comprising:

3 a controller receiving a plurality of colored signals, performing a predetermined signal
4 processing, and outputting color data in accordance with said signal processing; and

5 an optical unit receiving said outputted color data, outputting image data corresponding to
6 said outputted color data to a screen via a first light path by displaying data in a sequence from
7 most significant bit to least significant bit and via a second light path by displaying data in a
8 sequence from least significant bit to most significant bit.

1 43. The apparatus of claim 42, said optical unit further comprising:

2 a first digital display panel receiving said outputted color data from said controller and

3 panel control signals for driving said first digital display panel in accordance with first
4 synchronization signals, said first display being located along said first light path; and

5 a second digital display panel receiving said panel control signals and said outputted color
6 data from said controller for driving said second digital display panel in accordance with second
7 synchronization signals, said second display being located along said second light path, said first
8 and second light paths being separately located.

1 44. The apparatus of claim 43, said optical unit further comprising:

2 an optical source generating and irradiating light;

3 a collimating lens collimating light irradiated from said optical source;

4 a color switching unit receiving the light from said collimating lens and sequentially
5 outputting optical signals;

6 a first polarized beam splitter splitting said outputted optical signals received from said
7 color switching unit according to a polarization of said outputted optical signals, conveying P
8 wavelength components of said outputted optical signals along said first light path, conveying S
9 wavelength components of said outputted optical signals along said second light path;

10 said first display being installed along said first light path, arranging bits so that said
11 outputted color data are displayed in order from most significant bit to least significant bit;

12 said second display being installed along said second light path, arranging bits so that said
13 outputted color data are displayed in order from least significant bit to most significant bit; and

14 a second polarized beam splitter splitting light received from said first and second

displays according to a polarization of the light received from said first and second displays.

45. The apparatus of claim 44, said sequentially outputted optical signals outputted from said color switching unit corresponding to red signals, green signals, and blue signals.

46. The apparatus of claim 44, said first and second displays being selected from among ferroelectric liquid crystal panels and liquid crystal display panels.

47. A false contour correcting method in an image display system, comprising:
receiving image data and supplying said image data to a first display arranging bits of said image data so that said image data is driven and displayed in order from most significant bit to least significant bit; and

supplying said image data to a second display arranging bits of said image data so that said image data is driven and displayed in order from least significant bit to most significant bit.

48. The method of claim 47, said first and second panels being selected from among transmissive and reflective liquid crystal display panels.

49. The method of claim 47, further comprising:
splitting said image data into a first light beam having P wavelength components and a second light beam having S wavelength components;

4 directing said first light beam to said first display;
5 directing said second light beam to said second display; and
6 guiding light received from said first and second displays to a screen to display on said
7 screen data corresponding to said image data.

ABSTRACT

A false contour correction apparatus and method in an image display system, by which a false contour at a place where conversion of the unit bits of data is severe on a display device driven in a digital system is corrected, is provided. According to the present invention as described above, received image data is displayed by reversely-symmetrically arranging the bits of two digital driving display means, so that fatal false contour during digital driving can be removed.

FIG. 1

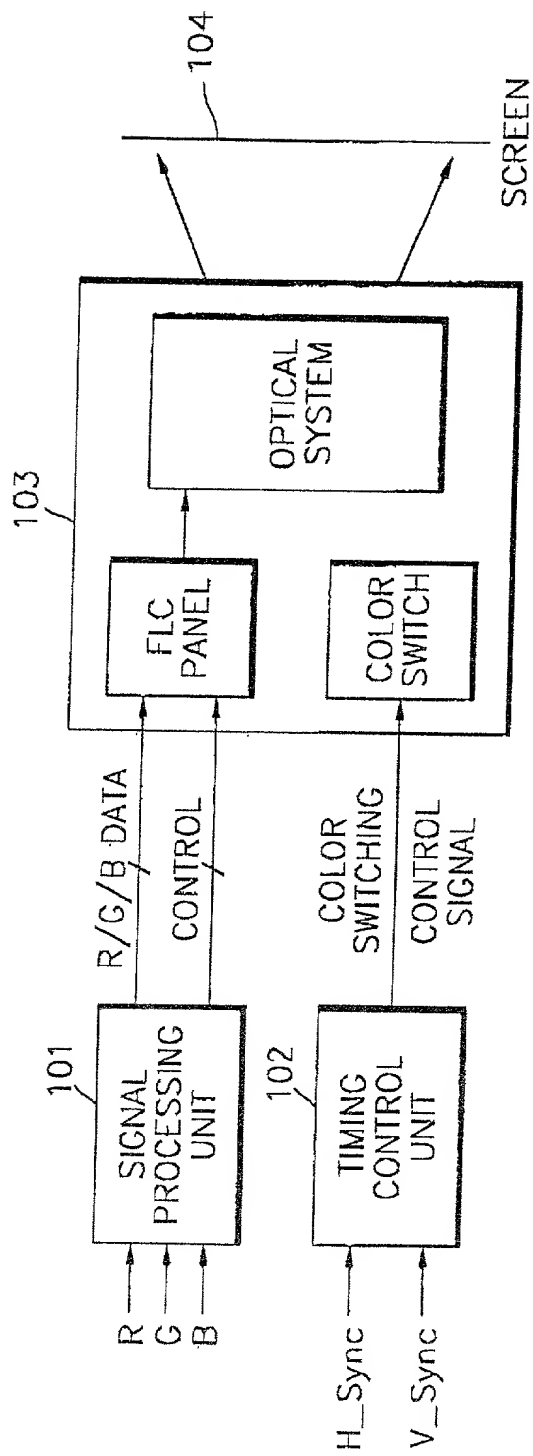


FIG. 2

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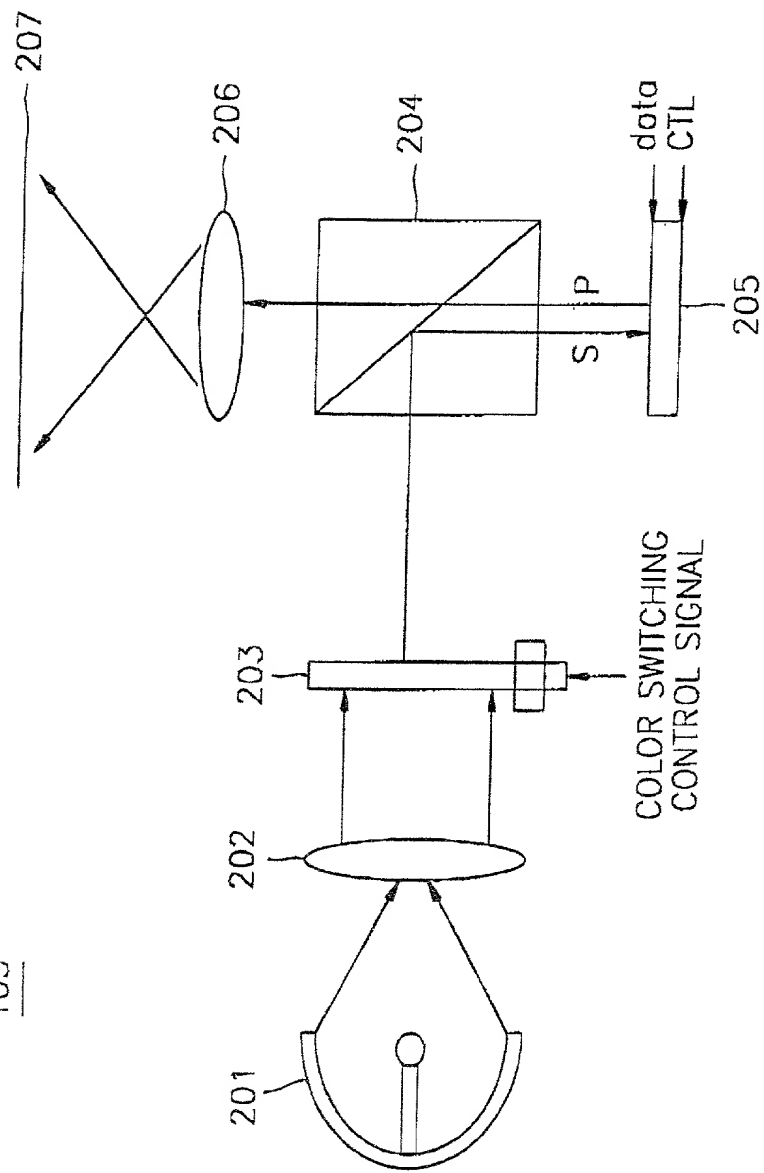


FIG. 3

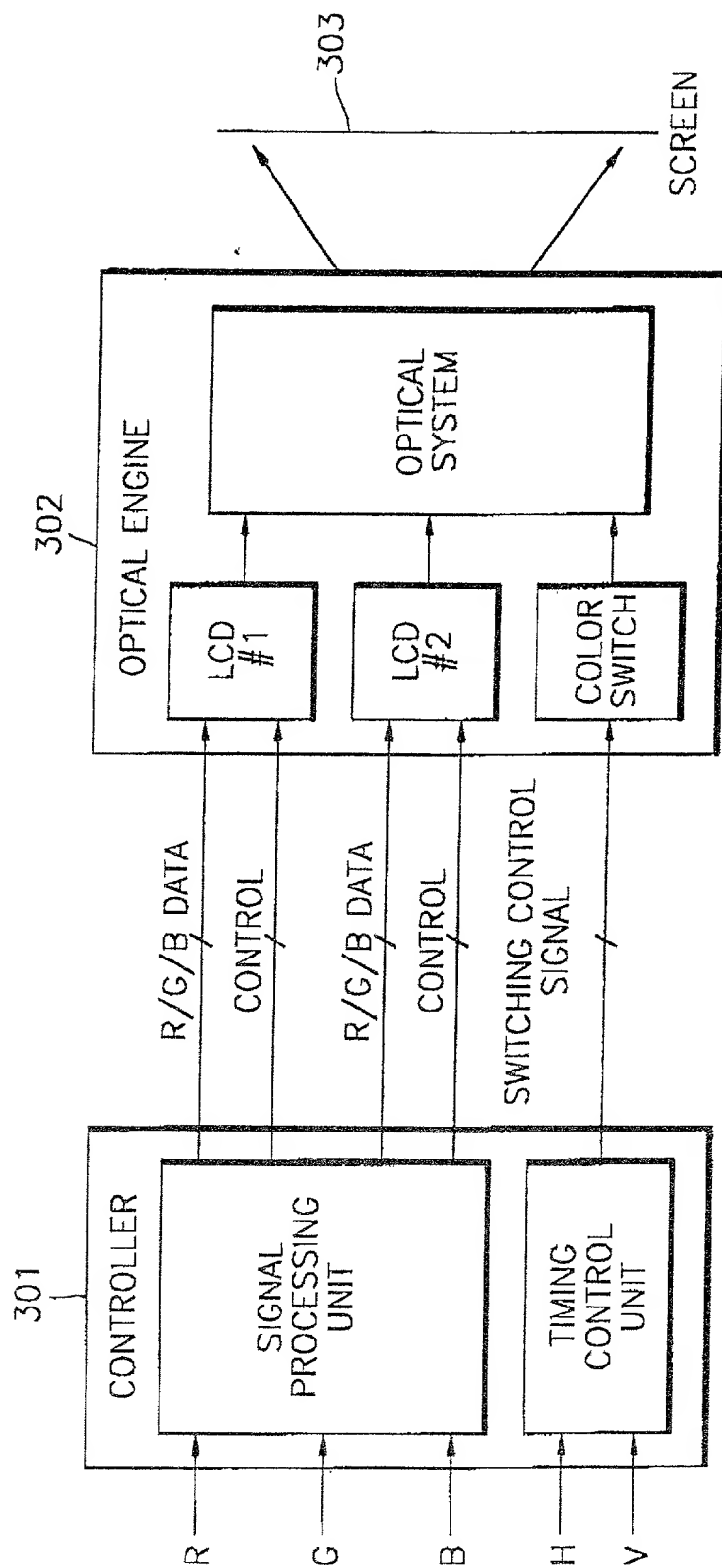
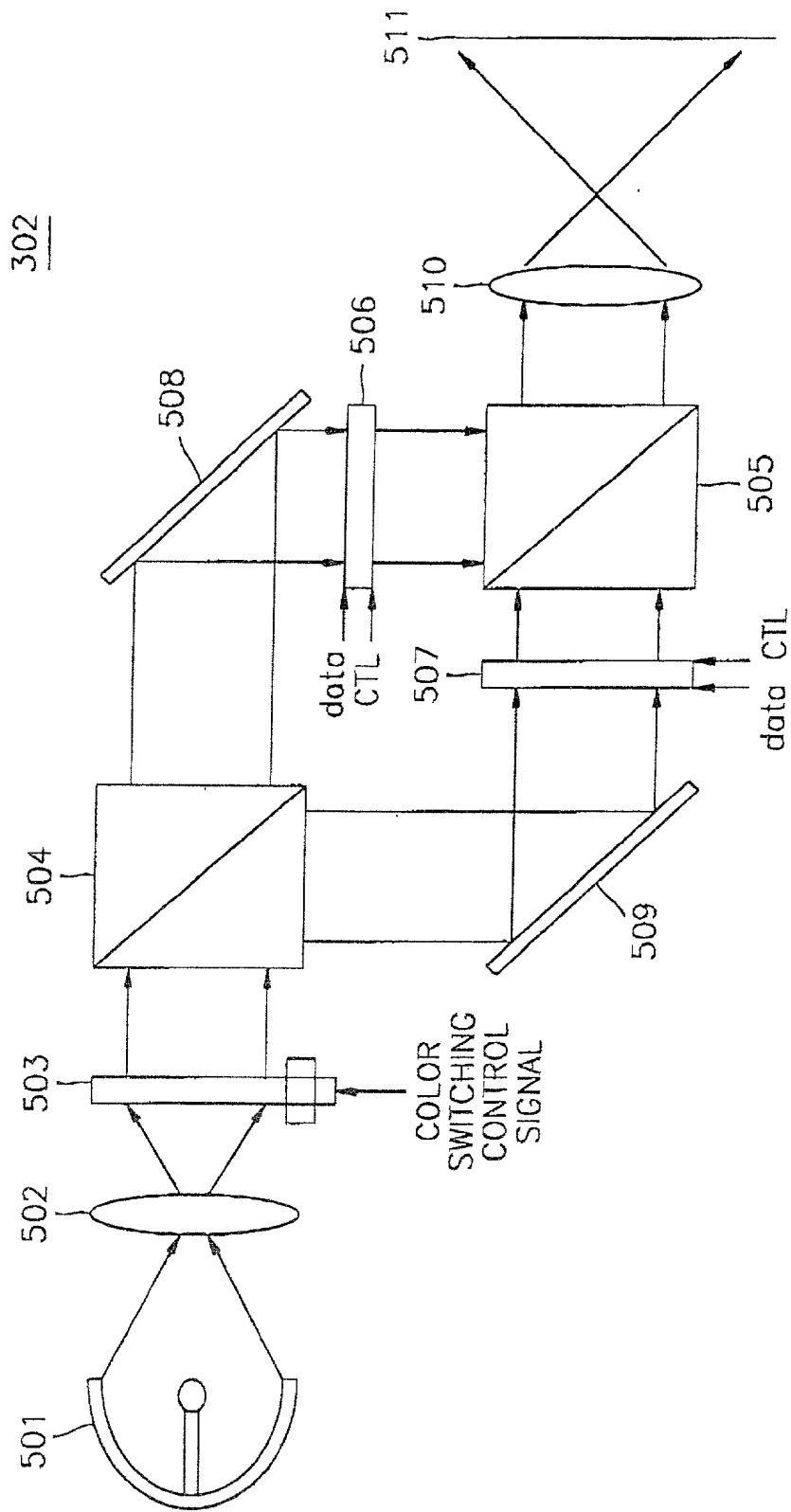


FIG. 5



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FIG. 6

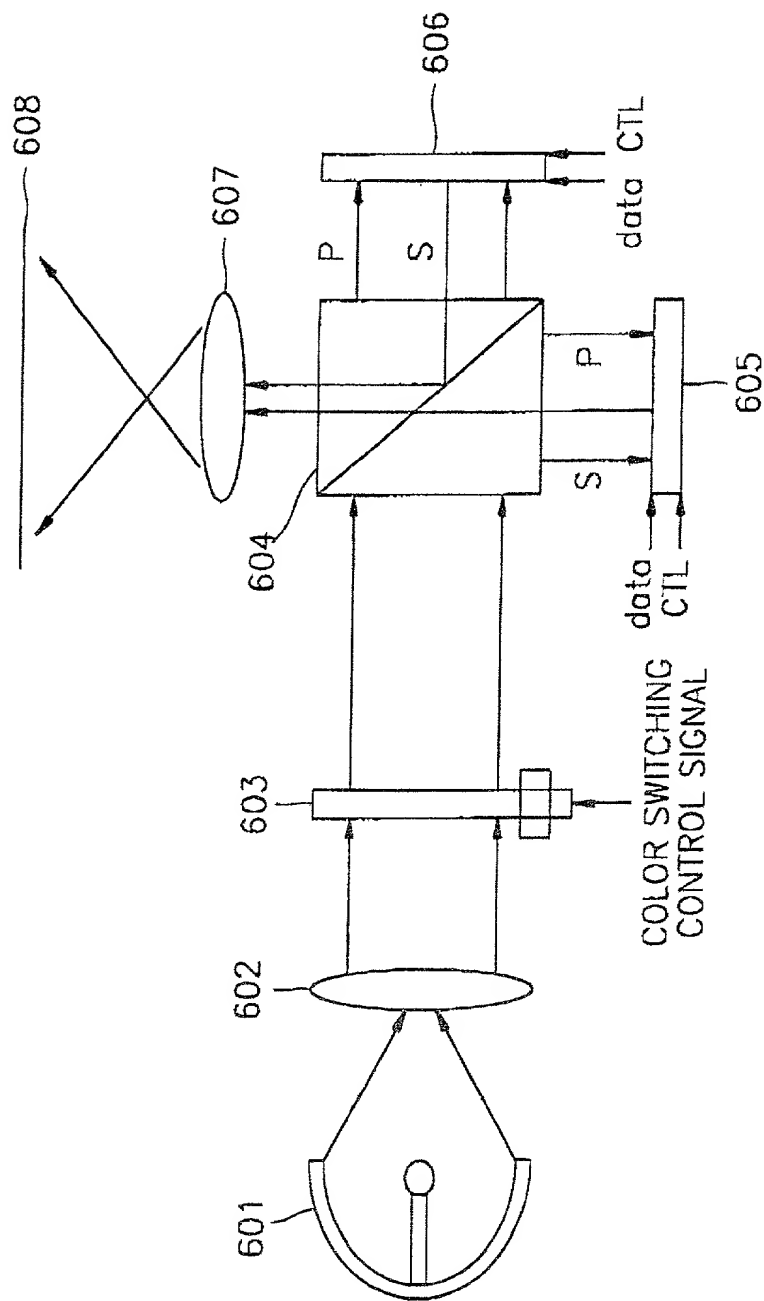
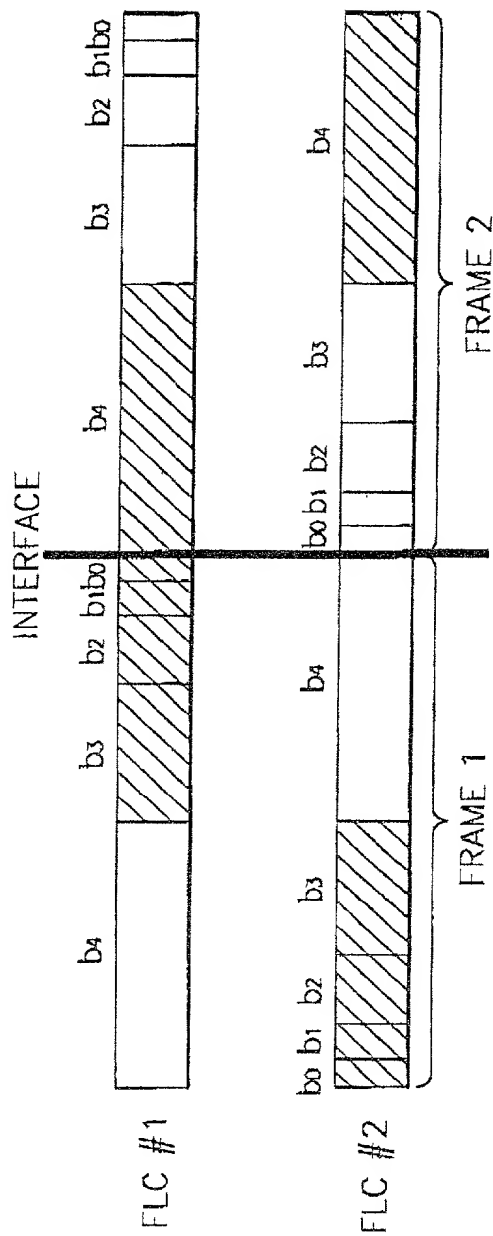


FIG. 7



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Young-Sun KIM

Serial No.: *To be Assigned*

Examiner: *To be Assigned*

Filed: 6 November 2000

Art Unit: *To be Assigned*

For: **FALSE CONTOUR CORRECTION APPARATUS IN IMAGE DISPLAY
SYSTEM AND FALSE CONTOUR CORRECTION METHOD**

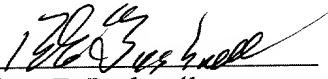
TRANSMITTAL OF DECLARATION

The Assistant Commissioner
of Patents
Washington, D.C. 20231

Sir:

Accompanying this transmittal is a Declaration for the above-referenced application.

Respectfully submitted,


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009071 62550260

DECLARATION

AS A BELOW NAMED INVENTOR, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe that I am the original, first and sole (if only one name is listed below), or an original, first and joint inventor (if plural names are listed below), of the subject matter which is claimed and for which a patent is sought on the invention entitled:

TITLE: FALSE CONTOUR CORRECTION APPARATUS IN IMAGE DISPLAY SYSTEM AND FALSE CONTOUR CORRECTION METHOD

the specification of which either is attached hereto or otherwise accompanies this Declaration, or:

☐ was filed in the U.S. Patent & Trademark Office on _____ and assigned Serial No. _____.

☐ and (if applicable) was amended on _____.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to patentability and to the examination of this application in accordance with Title 37 of the Code of Federal Regulations §1.56. I hereby claim foreign priority benefits under Title 35, U.S. Code §119(a)-(d) or §365(b) of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT International application which designated at least one country other than the United States, or §119(e) of any United States provisional application(s), listed below and have also identified below any foreign applications for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

49105/1999 (Application Number)	Republic of Korea (Country)	6 November 1999 (Day/Month/Year filed)	Priority Claimed: Yes [X] No []
65047/2000 (Application Number)	Republic of Korea (Country)	2 November 2000 (Day/Month/Year filed)	Yes [X] No []

I hereby claim the benefit under Title 35, U.S. Code, §120, of any United States application(s), or §365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application(s) in the manner provided by the first paragraph of Title 35, U.S. Code, §112, I acknowledge the duty to disclose information material to patentability as defined in Title 37, The Code of Federal Regulations, §1.56(a) which became available between the filing date of the prior application and the national or PCT international filing date of this application:

_____ (Application Serial No.)	_____ (Filing Date)	_____ (STATUS: patented, pending, abandoned)
_____ (Application Serial No.)	_____ (Filing Date)	_____ (STATUS: patented, pending, abandoned)

I hereby revoke all previously granted powers of attorney and appoint the following attorneys: Robert E. Bushnell, Reg. No. 27,774, Michael D. Parker, Reg. No. 34,973, and Darren R. Crew, Reg. No. 37,806, to prosecute this application and to transact all business in the U.S. Patent & Trademark Office connected therewith and with any divisional, continuation, continuation-in-part, reissue or re-examination application, with full power of appointment and with full power to substitute an associate attorney or agent, and to receive all patents which may issue thereon, and request that all correspondence be addressed to:

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Area Code: 202-408-9040

I HEREBY DECLARE that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 U.S. Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Inventor's signature: _____ Date: _____
Residence & Post Office Address: _____

FULL NAME OF THIRD JOINT INVENTOR: _____ Citizenship: _____

Inventor's signature: _____ Date: _____
Residence & Post Office Address: _____

FULL NAME OF FOURTH JOINT INVENTOR: _____ Citizenship: _____

Inventor's signature: _____ Date: _____
Residence & Post Office Address: _____

☐ Additional inventors are being named on separately numbered sheets attached hereto.